

METHOD OF AND APPARATUS FOR CORRECTING COLOR  
OF PRINT MEDIUM, AND PROOFER USED THEREIN

BACKGROUND OF THE INVENTION

Field of the Invention:

The present invention relates to a method of and an apparatus for correcting the color of a print medium and a proofer such as a color printer or the like, in a proof generating system which generates a color proof comprising a color image printed on a proof sheet with the proofer, before a colored printed material is produced using a print sheet by a color printing machine such as a rotary press or the like.

Description of the Related Art:

It has heretofore been customary to generate a color proof for examining colors and making color corrections with a proofer such as a color printer or the like before a colored printed material with a color image in the form of a halftone-dot image printed on a print sheet as a final product is produced by a color printing machine.

The proofer is used because it does not require films and printing plates (presensitized plates) to be produced and can easily generate a plurality of hard copies or color proofs within a short period of time.

For forming a color image on a proof sheet, image data depending on a device such as a printing machine, a camera, an image sensor, a CRT, an LED, etc., e.g., C, M, Y, K (cyan,

magenta, yellow, black) image data, are converted to colorimetric data independent of a device, e.g., X, Y, Z (stimulus value) data, according to a standard printing profile (a four-dimensional lookup table or the like) given by a printer manufacturer or the like. Then, the device-independent colorimetric data are converted to device-dependent image data for a color printer, e.g., R, G, B (red, green, blue) image data, according to a proofer profile, e.g., a printer profile (a three-dimensional lookup table). Using the device-dependent image data, a color proof with a color image formed on a proof sheet is generated by a color printer which is also referred to as a proof printer. In this manner, the colors of a printed material to be produced by the printing machine can be simulated by the color proof thus generated before the printed material is actually produced.

However, it often happens for the standard printing profile to fail to match printing properties, i.e., printing conditions depending on inks, papers, and printing machine characteristics, of the printing machine which will actually be used to print the color image.

Specifically, the printing conditions vary depending on many parameters which include not only inks, papers, printing machine types, but also production lots and ambient temperatures even when the same inks, paper, and printing machine are used. It is impossible for the standard printing profile to fully match actual printing conditions

used by the user, i.e., desired printing conditions. It is therefore necessary to adjust the printing profile according to actual printing conditions, i.e., desired printing conditions, rather than standard printing conditions.

5           Inks and papers that are in general use are limited to certain types. Therefore, solid ink colors and paper colors are relatively stable even under different printing conditions. However, intermediate color tones may vary greatly depending on conditions in which color images are printed by an actual printing machine. For adjusting such intermediate color tones, it has been the practice to insert one-dimensional lookup tables for the respective colors C, M, Y, K to adjust C, M, Y, K tone curves (also referred to as gradation characteristics or dot gains) prior to the four-dimensional lookup table as the standard printing profile, and convert the respective colors C, M, Y, K to C', M', Y', K', respectively, for color correction.

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20           If the proofer is a CMYK printer capable of using print sheets for finally printing color images thereon, then when such print sheets of the same type and lot as will be used by the actual printing machine are used by the proofer, color images printed on print proofs by the proofer can be confirmed as reflecting finally printed color images substantially exactly.

25           However, if sheets used by the proofer are of the type for exclusive use by the proofer and are different from print sheets according to the standard printing profile for

use by the actual printing machine, then adjustments need to be made because the color of the print sheets themselves does not match the gradation (dot gain) of highlights (lightly tinted areas). Such adjustments can be made to a certain extent by adjusting the tone curves with the one-dimensional lookup tables. However, the sheet color can only be adjusted in principle by increasing the amount of inks. If the sheet color is adjusted, then not only the sheet color, but also the dot gain of lightly tinted areas or highlights is varied, and it is not clear how the dot gain of lightly tinted areas or highlights is to be adjusted.

According to the conventional practice in which proofs are produced by the proofer using dedicated sheets, if the color of print sheets to be used by the actual printing machine is lighter than the color of print sheets according to the standard printing profile, then it is impossible to adjust the dot gain with the sheet color.

#### SUMMARY OF THE INVENTION

It is therefore an object of the present invention to provide a method of and an apparatus for correcting the color of sheets, more generally, the color of a print medium into a lighter tint, and correcting the color of a print medium, i.e., the difference between the color of a standard print medium and the color of a desired print medium, without affecting the dot gain.

Another object of the present invention is to provide a

proofer for generating a color proof having good color reproduction, on a proof print medium having the color different from the color of the desired print medium.

The above and other objects, features and advantages of the present invention will become more apparent from the following description when taken in conjunction with the accompanying drawings in which a preferred embodiments of the present invention is shown by way of illustrative example.

#### BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 is a block diagram of a proof generating system to which the principles of the present invention are applied;

FIG. 2 is a view of a color chart, which is a printed image outputted by a printer, carrying patches that represent colorimetric values  $L^*a^*b^*$  of the color of a print sheet to be actually printed and values which vary successively slightly from the colorimetric values  $L^*a^*b^*$ ;

FIG. 3 is a view showing a comparison between the colors of the color patches on the color chart shown in FIG. 2 and the color of a print sheet to be actually printed; and

FIG. 4 is a view of a color chart, in which a color of a central color patch in FIG. 2 is same as a color of a color sheet and colors of remaining color patches are changed correspondingly.

## DESCRIPTION OF THE PREFERRED EMBODIMENTS

As shown in FIG. 1, a proof generating system 10 to which the principles of the present invention are applied has a color converter 12 in the form of a computer. The color converter 12 converts image data depending on an input device, e.g., C, M, Y, K image data  $I_{in} = I_{in}(C, M, Y, K)$  to be printed, each of halftone-dot % data, to device-dependent image data, e.g., R, G, B image data  $I_{out} = I_{out}(R, G, B)$ , and outputs the R, G, B image data to an image output device as a proofer body, e.g., a printer 14. In this embodiment, the proofer comprises the color converter 12 and the printer 14 as the proofer body.

The C, M, Y, K image data  $I_{in}$  are image data generated by a color separator 18 which converts R, G, B image data generated by an image input device, e.g., a scanner 16, according to a three-color to four-color conversion process (RGB  $\rightarrow$  CMYK) to suit printing properties. The color separator 18 makes known color corrections, gradation corrections, and other corrections, which will not be described in detail below as they do not have a direct bearing on the present invention.

The color converter 12 connected to an output terminal of the color separator 18 has one-dimensional conversion lookup tables (LUTs) 21 through 24 for effecting gradation conversion on each of the colors C, M, Y, K of the C, M, Y, K image data  $I_{in}$  from the color separator 18, and a standard printing profile (given color converting means) 26 for

converting gradation-converted image data  $I_{in}'$  ( $C'$ ,  $M'$ ,  $Y'$ ,  $K'$ ) from the LUTs 21 through 24 to X, Y, Z colorimetric data  $I_{cv} = I_{cv}(X, Y, Z)$  as first colorimetric data which are device-independent image data.

5           The color converter 12 also has one-dimensional conversion LUTs (color correcting means, also mentioned as a color adjusting function, a color adjusting block, or a color adjuster) 31 through 33 for effecting colorimetric conversion on the X, Y, Z colorimetric data  $I_{cv}$  to second colorimetric data  $I_{cv}' = I_{cv}'(X', Y', Z')$ .

10           The color converter 12 further has a printer profile (color converting means) 36 for converting the second colorimetric data  $I_{cv}'$  to the R, G, B image data  $I_{out} = I_{out}(R, G, B)$ .

15           When the R, G, B image data  $I_{out}$  are supplied to the printer 14, the printer 14 generates a proof 42 which carries a color image 39 on a color sheet 40 that is a dedicated proof print medium.

20           The printer 14 may comprise a laser beam printer which scans the color sheet 40 with R, G, B laser beams intensity-modulated by the R, G, B image data  $I_{out}$  to record latent images, and develops the recorded latent images into visible R, G, B images. The color sheet 40 hereinafter refers to a developed color sheet.

25           Processes of generating the LUTs 21 through 24 for correcting gradation (dot gain) characteristics, the standard printing profile 26, the colorimetric conversion

LUTs 31 through 33, and the printer profile 36 will be described below.

The printer profile 36 is given by a printer manufacturer or the like. For generating the printer profile 36, color patches of combinations of the colors R, G, B of the R, G, B image data Iout, each ranging from a zero value to a maximum value, are produced on the color sheet 40, and measured by a colorimeter to determine X, Y, Z colorimetric data. Then, a conversion table between the R, G, B image data and the X, Y, Z colorimetric data is generated. The generated conversion table is inversely converted and interpolated, if necessary, thereby producing a LUT as the printer profile 36 for converting X, Y, Z colorimetric data (the colorimetric data Icv' in FIG. 1) to R, G, B image data Iout.

The printing profile 26 is also given by a printer manufacturer or the like. The printing profile 26 is a colorimetric table of values of C, M, Y, K halftone-dot % data at certain intervals. For generating a colorimetric table of values of C, M, Y, K halftone-dot % data at intervals of 10 %, for example, it is necessary to determine a total of  $11^4 = 14641$  colorimetric values of the four colors C, M, Y, K at 0, 10, ..., 100 halftone-dot %. Actually, however, several hundred representative colors of these 14641 colorimetric values are printed as a chart on a standard print sheet by a standard printing machine, and then colorimetrically measured to generate a colorimetric



table of values of C, M, Y, K halftone-dot % data at intervals of 10 % as the standard printing profile 26, which is a nonlinear four-dimensional LUT for converting the image data  $I_{in}' (C', M', Y', K')$  to the colorimetric data  $I_{cv} (X, Y, Z)$ .

When halftone-dot % data  $C', M', Y', K'$  of the image data  $I_{in}' (C', M', Y', K')$  are supplied to the printing profile 26, the printing profile 26 converts the halftone-dot % data  $C', M', Y', K'$  to the X, Y, Z colorimetric data  $I_{cv} = I_{cv} (X, Y, Z)$  as the first colorimetric data.

As described above, the printing profile 26 requires a very large scale of colorimetric operations to be carried out for making itself highly accurate for color conversion.

The printing profile 26 is provided as a standard printing profile by the printer manufacturer. The standard printing profile 26 is designed to cover different papers including art paper, coat paper, mat paper, and wood free paper, two or three types of ink each having a high market share, and a printing machine having a high market share, which is supposed to operate at normal temperature.

The LUTs 21 through 24 for correcting gradation (dot gain) characteristics serve to convert C, M, Y, K halftone-dot % data of the C, M, Y, K image data  $I_{in} \{I_{in} = I_{in} (C, M, Y, K)\}$  to  $C', M', Y', K'$  halftone-dot % data of the gradation-converted image data  $I_{in}' \{I_{in}' = I_{in}' (C', M', Y', K')\}$ .

As described above with respect to the related art,

since inks and papers that are in general use are limited to certain types, solid ink colors and paper colors are relatively stable even under different printing conditions. However, intermediate color tones may vary greatly depending on conditions in which color images are printed by an actual printing machine. For adjusting such intermediate color tones, it is necessary to insert one-dimensional C, M, Y, K LUTs 21 through 24 for adjusting C, M, Y, K tone curves (dot gains) prior to the four-dimensional LUT as the standard printing profile 26, and convert the respective colors C, M, Y, K to C', M', Y', K', respectively, for color correction.

For example, if the tone curves (tone curves under desired printing conditions) of a printing machine to be used as the printer 14 to produce the proof 14 are more upwardly convex than the tone curves of the given standard printing profile 26 (which normally agree with a straight line  $y = x$  in an orthogonal plane  $xy$  at values of 0 and 100 %, but are upwardly convex with respect to the straight line  $y = x$  in an intermediate section between the values of 0 and 100 %), then the LUTs 21 through 24 may incorporate upwardly convex curves to compensate for the difference between the tone curves. Conversely, if the tone curves of a printing machine to be used as the printer 14 are more downwardly convex than the tone curves of the given standard printing profile 26, then the LUTs 21 through 24 may incorporate downwardly convex curves to compensate for the difference between the tone curves.

Even with the corrective one-dimensional tone curves incorporated in the LUTs 21 through 24, if the color of print sheets to be used actually is lighter than the color of print sheets according to the standard printing profile 26 (colorimetric values X, Y, Z outputted from the standard printing profile 26 when the input image data Iin' have values of  $C' = M' = Y' = K' = 0$ ), then the gradations cannot accurately be converted in highlights (tint areas of the intermediate color tones) including the sheet color.

In order to correct the sheet color into a lighter tint, the colorimetric conversion LUTs 31 through 33 are employed. For generating the colorimetric conversion LUTs 31 through 33, the input image data Iin' having values  $Iin' = 0$  ( $C' = M' = Y' = K'$ ) are supplied to the printing profile 26, which output X, Y, Z colorimetric values X0, Y0, Z0.

The X, Y, Z colorimetric values X0, Y0, Z0 are then mathematically converted to colorimetric values  $L^*a^*b^*$  (hereinafter referred to as colorimetric values of the sheet color according to the printing profile 26) in a CIELAB color space according to a known conversion formula.

Thereafter, each of the colorimetric values  $L^*a^*b^*$  of the sheet color according to the printing profile 26 is varied about itself. Specifically, the value of  $L^*$  relative to luminance is slightly varied about the colorimetric value  $L^*$ , thereby to calculate values of  $L^* \pm \Delta L$ ,  $L^* \pm 2\Delta L$ . Similarly, the value of  $a^*$  substantially relative to red is slightly varied about the colorimetric value  $a^*$ , thereby to

calculate values of  $a^* \pm \Delta a$ ,  $a^* \pm 2\Delta a$ . Furthermore, the value of  $b^*$  substantially relative to yellow is slightly varied about the colorimetric value  $b^*$ , thereby to calculate values of  $b^* \pm \Delta b$ ,  $b^* \pm 2\Delta b$ .

5 Then, the colorimetric value  $L^*$  of the sheet color according to the printing profile 26 and the calculated values of  $L^* \pm \Delta L$ ,  $L^* \pm 2\Delta L$ , the colorimetric value  $a^*$  of the sheet color according to the printing profile 26 and the calculated values of  $a^* \pm \Delta a$ ,  $a^* \pm 2\Delta a$ , the colorimetric value  $b^*$  of the sheet color according to the printing profile 26 and the calculated values of  $b^* \pm \Delta b$ ,  $b^* \pm 2\Delta b$  are converted to colorimetric data  $X$ ,  $Y$ ,  $Z$  according to a known conversion formula.

10 ~~The colorimetric data  $X$ ,  $Y$ ,  $Z$  thus obtained comprise~~  
15 all combinations of the colorimetric values. Combinations about  $(L^*, a^*, b^*)$  are 25 combinations including one combination of  $(L^*, a^*, b^*)$ , two combinations of  $(L^*, a^* \pm \Delta a, b^*)$ , two combinations of  $(L^*, a^* \pm 2\Delta a, b^*)$ , two combinations of  $(L^*, a^*, b^* \pm \Delta b)$ , two combinations of  $(L^*, a^*, b^* \pm 2\Delta b)$ , four combinations of  $(L^*, a^* \pm \Delta a, b^* \pm \Delta b)$ , four combinations of  $(L^*, a^* \pm \Delta a, b^* \pm 2\Delta b)$ , four combinations of  $(L^*, a^* \pm 2\Delta a, b^* \pm \Delta b)$ , and four combinations of  $(L^*, a^* \pm 2\Delta a, b^* \pm 2\Delta b)$ . Therefore, there are a total of 125 combinations.

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25 The 125 combinations of Lab data are converted to  $X$ ,  $Y$ ,  $Z$  data. The converted  $X$ ,  $Y$ ,  $Z$  data, as the second colorimetric data  $I_{cv}' = I_{cv}'(X', Y', Z')$ , are converted to

the R, G, B image data Iout {Iout = (R, G, B)} by the printer profile 36. The R, G, B image data Iout are then arrayed in a predetermined sequence, and supplied to the printer 14, which produces a color chart 42A composed of an array of color patch groups 61 through 65. The color chart 42A shows that color patches are arranged in respective cross sections across L\*-axes having different L\* values (for a\*- b\* planes) in three-dimensional colorimetric values L\*a\*b\*.

FIG. 2 schematically shows the color chart 42A. In FIG. 2, the colors of the color patches vary at small intervals of  $\Delta L$ ,  $\Delta a$ ,  $\Delta b$  in the CIELAB color space, rather than the CIEXYZ, because they are believed to match human vision characteristics more effectively than the values X, Y, Z.

As shown in FIG. 2, the color chart 42A comprises a color sheet 40 carrying the five color patch groups 61 through 65 composed of  $5 \times 25 = 125$  color patches. A color patch 73, represented by ■, at the center of the central color patch group 63, for example, is formed of the colorimetric values L\*a\*b\* of the sheet color according to the printing profile 26. Color patches positioned on the right of the color patch 73 have colorimetric values incremented by  $+\Delta a$  in the rightward direction. Therefore, a color patch 74, for example, corresponds to colorimetric values (L\*,  $a^* + 2\Delta a$ ,  $b^* + \Delta b$ ). As shown in FIG. 3, a print sheet 80 to be actually used for printing (corresponding to desired printing conditions) is prepared, and partly

superposed on the color patches of the color patch groups 61 through 65. The user then visually compares the color of the print sheet 80 and the color patches on the color chart 42A with each other to confirm a color difference.

5           Inasmuch as the color of the color sheet 40 is lighter than the color of the print sheet 80, it is possible for the user to easily locate a color (color patch) that is substantially the same as the color of the print sheet 80 through a visual observation. When the user spots a color patch whose color cannot be distinguished from the color of the print sheet 80, the colorimetric data of the spotted color patch, stated otherwise, the input values supplied to the printer profile 36 (either of the X, Y, Z data converted from the 125 combinations of the Lab data) are regarded as colorimetric data  $X_\alpha$ ,  $Y_\alpha$ ,  $Z_\alpha$ .

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20           If the colorimetric values of the sheet color according to the printing profile 26 are X, Y, Z colorimetric values  $X_0$ ,  $Y_0$ ,  $Z_0$  converted from the colorimetric values  $L^*a^*b^*$  of the sheet color according to the printing profile 26, then since the X, Y, Z colorimetric values are generally linear, gradients of  $X_\alpha/X_0$ ,  $Y_\alpha/Y_0$ ,  $Z_\alpha/Z_0$  are incorporated in the respective LUTs 31 through 33.

25           Therefore, the colorimetric data X, for example, supplied to the LUT 31 is converted thereby to colorimetric data  $X'$  ( $= X \times X_\alpha/X_0$ ), and the colorimetric data Y, Z are also converted thereby to colorimetric data  $Y'$  ( $= Y \times Y_\alpha/Y_0$ ) and  $Z'$  ( $= Z \times Z_\alpha/Z_0$ ). Based on the converted colorimetric

data  $X'$ ,  $Y'$ ,  $Z'$ , the gradation (dot gain) in the vicinity of highlights of the image 39 on the color sheet 40 of the proof 42 produced by the printer 14 can be corrected.

If the user has a colorimeter, then it is not necessary to produce the color chart 42A, but the user may colorimetrically measure the color of the print sheet 80 to be used actually, and use the produced colorimetric data as the above colorimetric data  $X\alpha$ ,  $Y\alpha$ ,  $Z\alpha$ .

As shown in FIG. 4, the color chart 42B may comprise a central color patch 73B having a same color as the one of the color sheet 40 (white color of the background) when the color of the print sheet 80 is determined by partly superposing the print sheet 80 on the color chart. Accordingly, directional relationships of the color changes from the paper color (the color without correction) can be easily understood.

In this case, when colorimetric values of the color paper 40 are assumed as  $(L^*1, a^*1, b^*1)$ , a color patch 74B, for example, in five color patch groups 61B-65B corresponds to colorimetric values  $(L^*1, a^*1 + 2\Delta a, b^*1 + \Delta b)$ .

Further, when a color difference between two closest color patches (e.g., between a color patch 73 and the eight color patches therearound) is assumed as  $\Delta E$  in the color chart 42A, the color difference  $\Delta E$  preferably has a value from 1.5 to 2, for allowing the user to visually distinguish between two closest color patches (also applicable to color patches in color chart 42B).

When outputting color chart 42A or the like in the above embodiment, increment/decrement intervals of colorimetric values  $L^*a^*b^*$  are set to be values of  $\pm \Delta$ ,  $\pm 2\Delta$  with respect to values  $L^*a^*b^*$  as values of  $\Delta$  multiplied by an integral number. However, the increment/decrement intervals may be adjusted or set to be values of  $\pm 1.5\Delta a$  as values of  $\Delta$  multiplied by a real number, for example, which are in the range of values between  $\pm \Delta$  and  $\pm 2\Delta$ , respectively, for outputting a color chart. The increment/decrement intervals of values  $L^*a^*b^*$  can also be set independently with each other, e.g.,  $\pm 1.5\Delta L$  for the value  $L^*$ ,  $\pm \Delta a$  for the value  $a^*$ , and  $\pm 2\Delta b$  for the value  $b^*$ .

According to this embodiment, as described above, the one-dimensional colorimetric conversion LUTs 31 through 33 for adjusting the sheet color are inserted behind the standard printing profile 26. With this arrangement, first, if a colorimeter is available to the user, then the user can directly correct the sheet color based on colorimetric values of the print sheet 80 which are obtained by the colorimeter. Second, the sheet color can be corrected into a tint lighter than the color sheet according to the standard printing profile 26 up to the level of lightness of the color of the color sheet 40. Third, tint areas of the intermediate color tones can appropriately be corrected while keeping the dot gain relationship without having to adjust the tone curves.

The above second and third advantages are independent



of each other such that tint areas of the intermediate color tones can appropriately be corrected while keeping the dot gain relationship no matter which direction the sheet color may be varied in.

5           As described above, the dot gain of the intermediate color tones may be corrected by the one-dimensional C, M, Y, K LUTs 21 through 24 placed in front of the printing profile 26.

10           In the above embodiment, since the sheet color, the dot gain in tint areas of the intermediate color tones, and the dot gain in other areas of the intermediate color tones can be corrected, the dot gain can be corrected in all areas of the intermediate color tones. Consequently, the sheet color may be corrected to reproduce an image whose colors are accurately representative of those of a printed image, on the color sheet 40.

15           Therefore, even if the color of a print medium to be used under desired printing conditions is lighter than the color of a print medium used under standard printing conditions, the color can easily be corrected into a lighter color according to calculations without affecting the dot gain.

20           The principles of the present invention are applicable to a proof generating system for generating a proof with an image output device when a printed material is to be produced using a desired print medium (which may typically be, but not limited to, a sheet of paper) different from a

standard print medium (which may typically be, but not limited to, a sheet of paper).

According to the present invention, furthermore, the color converting means given to a standard print medium converts device-dependent image data to first colorimetric data, and the color correcting means for correcting the difference between the color of a desired print medium and the standard print medium converts the first colorimetric data to second colorimetric data. Based on the second colorimetric data, the image output device produces a proof on which the difference between the color of the desired print medium and the standard print medium has been corrected.

Because the color is colorimetrically corrected, a corrective range that is achieved is wide. If the color of the standard print medium produced by the color converting means is different from the color of the desired print medium to be used, e.g., even if the color of the desired print medium is lighter than the color of the standard print medium, the difference between those colors may be corrected.

Before the device-dependent image data are converted to the first colorimetric data by the color converting means, the device-dependent image data are converted in gradation with respect to each color in order to match desired printing conditions for thereby correcting the intermediate color tones, and the sheet color and tints in highlights can be corrected by colorimetric corrections effected by the

color converting means.

5 The color correcting means may be generated by outputting color patches, whose colorimetric values are varied in a colorimetric color space about the color of the standard print medium, on a proof medium with the image output device, and visually comparing the color of the desired print medium with the colors of the color patches on the proof medium.

10 The color correcting means may alternatively be generated by colorimetrically measuring the color of the desired print medium.

15 In the color converter 12 of the above embodiment, at least the printing profile 26, the conversion LUTs 31 through 33 for effecting colorimetric conversion, and the printer profile 36 may be combined to be a synthetic LUT (combined LUT) 37 as one synthetic color converting means (combined color converting means). This configuration realizes fast conversion process in the color converter 12.

20 Although a certain preferred embodiment of the present invention has been shown and described in detail, it should be understood that various changes and modifications may be made therein without departing from the scope of the appended claims.